

Groundwater Formation and the Ecological State of Springs in the Central Part of the Volga-Don Interfluve

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Abstract — Groundwater plays a vital role in the development of the Central part of the Volga-Don interfluve, especially in those settlements where it is the only source of water supply. Material for the study of this territory included the collection and analysis of literary sources, the study of maps. 19 springs were studied expeditionary from April to November 2010–2013 and 2016–2018. The district is located within the Volga-Khoper and Donetsk-Don artesian basins of reservoir waters. Groundwater is confined to all divisions of the sedimentary strata of the basins. Distribution of operational resources of fresh groundwater in the Central part of the Volga-Don interfluve is uneven. The greatest capacity of fresh water is in the Northern part on the border of Gorodishchensky and Dubovsky districts of the Volgograd region - 400 m. Average indicators are observed in the West of the district - up to 200 m. In the central part of the interfluve, a small strip stretches from the southwest to the northeast, where the freshwater capacity is 100 m. Forecast resources of the Central part of the Volga-Don interfluve are 56 thousand m³/day, where with mineralization up to 1.0 g / dm³-52.1 thousand m³/day, which allows the study area to be attributed to areas partially provided with fresh groundwater. Studies have shown that the water quality in some springs does not meet the requirements of GOST (Russian Federal Standard) 2874-82. Indicators are greatly exceeded according to various chemical elements. Their presence in excess of the norm indicates a negative human impact. In most springs, water quality meets sanitary and epidemiological requirements.

Keywords: *groundwater, springs, Volga-Don interfluve, ecological state of springs*

I. INTRODUCTION

Groundwater plays a vital role in the development of the Central part of the Volga-Don interfluve, especially in those settlements where it is the only source of drinking, household and technical water supply. Groundwater is of great importance in the water supply of the studied region,

being environmentally friendly and safe in sanitary and epidemiological terms compared to surface sources.

In modern development conditions of industry, agriculture, housing and communal services and growth of settlements, the impact on the environment is increasing [1]. It is expressed in an increased amount of pollutants entering the hydrographic network from anthropogenic sources, which is a potential danger to human health.

II. MATERIALS AND METHODS (THE MODEL)

The methodology of the study included the collection and analysis of literature, the study of topographic maps and decryption of satellite images with the preparation of primary cartographic material. The springs identified as a result of processing of satellite images, cartographic materials and literary data were studied expeditionary.

During the study of springs, mathematical methods, hydrological methods (determination of temperature, transparency and turbidity of water, color, smell and taste), hydrochemical methods (determination of acid-base balance of water, silver ions) were used, the water flow rate of the studied springs was determined. The study of physical parameters of water was carried out by the method of T. P. Ikher (1997), measurement of flow rate, sampling of water from sources was carried out by the method of A. S. Bogolyubov (2001). Field studies were conducted in the warm season from April to November 2010-2013 and 2016-2018.

Natural diversity and geo-ecological conditions of natural groundwater outputs of the Volgograd region are among the little-studied areas of knowledge. Most of the works devoted to the natural water ingresses of the region are carried out in a practical aspect without detailed consideration of the springs' features. Monographs written under the guidance of Brylev V.A. Professor, doctor of

geographical Sciences VSSPU [2, 3] and some scientific articles by various authors [4-7] can be considered as the largest works devoted to this problem. Annually, the state of groundwater is reported in papers on the state of the environment of the Volgograd region [8-10].

III. RESULTS AND DISCUSSION

A. *Characteristics of geological and geomorphological conditions for the formation of springs in the Central part of the Volga-Don interfluvium.*

The district is located within the Volga-Khoper and Donetsk-Don artesian basins of reservoir waters. Groundwater is confined to all divisions of the sedimentary strata of the basins. Aquifers systems of Devonian and middle-upper Carboniferous deposits are represented by a series of water-bearing horizons connected by carbonate, more rarely by sandy formations and are widely distributed. In General, this complex of rocks is characterized by the presence of high-pressure mineralized waters and sodium chloride brines [8-10].

Permo-Triassic complex of sediments is represented by water-resistant rocks separating fresh and slightly saline waters of Meso-Cenozoic from salty waters and brines of Carboniferous and Devonian.

Jurassic and Cretaceous aquifers and water-bearing horizons (except for the Albs) are confined to thin sand interbed among clays, and are characterized by low water-inflow.

The greatest distribution and abundance of the Mesozoic aquifer units are represented by the Alb-Cenomanian. It is confined to a thick sand series with clays layers, throughout containing water of satisfactory quality.

Paleogene deposits composing the northeastern and Eastern part of the Volga-Don interfluvium contain several storeyed low-power water-bearing horizons of little practical importance.

Neogene-Quaternary sand-clay deposits containing groundwater are of paramount importance for water supply purposes.

Unloading of the first ones from the surface of water-bearing horizons occurs in the valleys of the rivers Mechetka, Tsaritsa, Pichuga, Rossoshka, Chervlenaya, Grachi, Karpovka, etc. Waters which are confined to the Quaternary, the Neogene and Paleogene rocks are of subsoil nature. While waters located in Mesozoic deposits, fractured rocks of the Paleozoic, in most cases are interstratified and pressure.

B. *The degree of groundwater supply in the Central part of the Volga-Don interfluvium.*

Distribution of operational resources of fresh groundwater in the Central part of the Volga-Don interfluvium is uneven. For example, the greatest capacity of fresh water is in the Northern part on the border of Gorodishchensky and Dubovsky districts of the Volgograd region - 400 m and more. Average indicators are observed in the West of the district - up to 200 m. In the central part of the district

stretches a small strip, where the freshwater capacity is 100 m.

Analysis of the dynamics of fresh groundwater intake in the district from 2001 to 2011 shows that the intake is gradually reduced from year to year, but the share in the total water intake in the region has changed-increased by 2 times. For example, in 2005, the share of territories located within the Central part of the Volga-Don interfluvium in the total water intake of the Volgograd region was the lowest for the entire period under review and amounted to 4.46 %, and in 2011 – the highest – about 9 %.

The forecast resources of the Central part of the Volga-Don interfluvium amounted to 56 thousand m³/ day, among them with mineralization up to 1.0 g/dm³ - 52.1 thousand m³/day, with a mineralization of 1.0-1.5 g/dm³- 1.7 thousand m³/day, with a mineralization of 1.5 – 3.0 g/dm³ - 2.2 thousand m³/day. This allows us to attribute the studied area to the territories partially provided with fresh groundwater.

Three underground water deposits have been explored on the territory of the district, two of which are intended for household and drinking water supply – the "Krasnyj pahar" field and the Volgograd field, and one - for the technical water supply - Rossoshinskoe. The leading position is occupied by Gorodishchenskoye field, located in Krasny Pahar' village [8].

Groundwater quality monitoring conducted in 2015 By the Committee of Natural Resources and Ecology of the Volgograd Region, revealed that within the region there are 4 focuses of technological pollution of groundwater, 3 of which belong to industrial facilities and 1 is a municipal facility. Thus, the Central part of the Volga-Don interfluvium occupies the 3rd position in terms of groundwater pollution. Neogene-Quaternary, Paleogene and Cretaceous water-bearing horizons and complexes, as well as hydraulically connected downstream hydrogeological subdivisions, are most often exposed to it.

C. *Analysis of the state of some springs in the study area*

According to official data, there are more than 50 springs in the Central part of the Volga-Don interfluvium. We have studied some of them: Svyataya Paraskeva Pyatnica, Uvarovskij, Pridorozhnyj, Gremuchij, Orlovskij, Krasnyj pahar', Kuz'michevskie (10 springs), Novaya Nadezhda and Serebryanyj Kolodec.

Water quality in most springs does not meet the requirements of GOST (Russian Federal Standard) 2874-82. Indicators are greatly exceeded according to various chemical elements (iron, manganese, fluorine, etc.). Their presence in excess of the norm indicates a negative anthropogenic impact.

The spring of *Svyataya Paraskeva Pyatnica* is located in Gorodishche village of the Volgograd region, at the base of the left slope of the Korennaya ravine. The spring is equipped and has three natural groundwater outputs. The first output is lined with stone and granite slabs, in the form of a hexagonal pool (it is abandoned and badly destroyed). The second and third outputs are captioned in the form of concrete wells, closed from external influence by slabs. A roof and gazebo are built over the wells (Fig. 1). The waters

of the spring are used for drinking for medical and recreational purposes. The spring is connected with the Tsaritsyn confining layer and is covered with 30-40 meter thick rocks. The discharge of the spring is 0.7 m/s. The type of the spring is ascending [2].

Spring *Uvarovskij* is located in the same village as the spring of Svyataya Paraskeva Pyatnica at the base of the right slope of the Korennaya ravine. In this area, it has the form of a slightly sloping terrace, the water of the spring, spilling over it, form a wetland, as evidenced by dense thickets of moisture-loving vegetation - sedge southern. The spring is arranged in the form of a stone quadrangular well, the base of which is cracked, and the water flows out of it, further flooding the area. Water surface in the well is open to external influence (Fig. 2). At the moment, it is in poor condition, so the local population has not used it for drinking for a long time. In the recent past, this spring had the status of a natural monument. Then the water quality in it was at a high level. The type of spring is ascending [2].

Orlovskij spring is located in the eponymous village of the Volgograd region, on the right slope of the Orlovka river valley (a tributary of the Mokraya Mechetka river), 50 meters from the Second Longitudinal highway. The spring is equipped. Four carved wooden pillars have a cruciform roof.



Fig. 1. Svyataya Paraskeva Pyatnica Spring (photo by A.Yu. Ovcharova)



Fig. 2. The current state of Uvarovskij spring (photo by A.Yu. Ovcharova)

Under it there is a low log house in the form of a well, which is closed with a metal lid. The area around the log house and under the gazebo is cemented. The waters of the spring flow into the Orlovka river. The water in the spring is clear, with the smell of fresh wood. Around the gazebo there is a low fence of logs in two rows, it can be used as a bench. In 2001, the spring was capped, the pump was installed and it was protected from external influences.

Yerzovskie springs are located in the eponymous village on the border of Gorodishchensky and Dubovsky districts of the Volgograd region. There are 10 springs in the village. Springs are formed in the lower horizon of Tsaritsyn deposits. Some of them are capped and protected from external influence by concrete walls and slabs, others have metal pipes coming out of the slopes of Yerzovsky Bay and its spurs. Types of springs are descending and ascending (Fig. 3).

Dumenko-1 spring is located in Yerzovka village on Dumenko street at the base of the left slope of the right ravine opening into Yerzovsky Bay. The depth of the ravine is 16 m. The spring is equipped in the form of concrete drainage well with a diameter of 120 cm, covered with a metal lid. At a distance of about 4 m from the well there is a metal pipe with a circumference of 56 cm. Around the well there is a metal fence (6 m x 6 m). The spring belongs to the Tsaritsyn tier (aquifer - greenish fine-grained sands). Type of spring – descending. Water quietly flows out of the grottoes at the base of the ravine, is collected in the drainage well, and flows along the bottom of the ravine, so the flow rate of the spring cannot be accurately measured, approximately – more than 2 l/sec (high-flow rate). The water temperature in the spring is +12°C. The water condition is satisfactory on the surface.



Fig. 3. Dumenko-1 spring in Yerzovka village (photo by A.Yu. Ovcharova)

Dumenko-2 spring is located in Yerzovka village on Dumenko street at the base of the left slope of the right ravine opening into Yerzovsky Bay, at a distance of about 20 m from the Dumenko-1 spring. The depth of the ravine is 13 m. The source is not capped, has about 10 natural outputs on the day surface. The spring belongs to the Tsaritsyn tier (aquifer - grey and grey-green sandstones, greenish fine-grained sands). Type of spring – descending. Water flows

quietly from the grottoes at the base of the ravine, forming a single drain. One of the outputs has a maximum flow rate of more than 1 l/s (high-flow), the water in it oozes from the sandstones. Water temperature is +12°C. The main outlet state of the spring is good on the surface. The water is crystal clear, pleasant to the taste (Fig. 4).

Volgolesosplav spring is located in Yertzovka village on Proletarskaya Street at the base of the left slope of the ravine opening into Yertzovsky Bay. A few hundred meters from the old Yertzovsky bridge. The depth of the ravine is 13 m. The spring is equipped in the form of concrete water storage well with a depth of 2 m and a diameter of 120 cm, which is covered with a concrete slab. At a distance of about 3 m from the well there is a metal pipe with a diameter of 13 cm. Water temperature is +12°C. The flow rate of the spring is more than 0.2 l/sec (low-rate). The spring belongs to the Tsaritsyn tier. The water condition is satisfactory on the surface. Type of spring – descending.

Serebryanyj spring is located in Yertzovka village at the base of the left slope of the Dubovaya ravine opening into Yertzovsky Bay. A few kilometers from the new Yertzovsky bridge. The depth of the ravine is 20 m. The spring belongs to the Tsaritsyn tier (aquifer - greenish fine-grained sands). Water temperature is +12°C. The flow rate of the spring is 0.5 l/sec (average flow rate). The spring is capped in the form of a metal pipe with a diameter of 13 cm, mounted in the base of the ravine. Type of spring – descending.

All of the above springs in Yertzovka village flow into the eponymous bay of the Volgograd reservoir and feed the Volga river.



Fig. 4. Dumenko-2 spring in Yertzovka village (photo by A.Yu. Ovcharova)

Kuz'michyovskij spring is located on the southern slope of the Konnaya ravine, 2 km North-East of Kuz'michi village in Volgograd region. The spring has two water outputs, located a few meters from each other, both are capped and equipped with pipes, one is metal with a diameter of 25 cm and the other is concrete with a diameter of 15 cm. The total flow rate of the spring is 2 l/sec. Water-bearing horizon of the spring is formed at the base of Ergenian deposits.

Krasnyj pahar' spring is located in Krasnyj pahar' village of Volgograd region, at the foot of the dam of the first pond in the bed of the Rossoshka river, at the bottom of its slope, in the distance of 1.5 km to North-East from the

eponymous village. At a distance of several meters, the spring flows into the Rossoshka river. Water-bearing horizon of the spring is formed at the base of Ergenian deposits. The spring is not equipped, so it is not possible to measure the flow rate, its waters, spilling over the ravine, form dense thickets of moisture-loving vegetation. The type of the spring is ascending.

Pridorozhnyj spring is located at the base of one of the spurs of the Gremyachaya ravine (500 m from Gorodishche village). It has three water outputs, two of which are equipped. Water-bearing horizon of the spring is formed at the base of Ergenian deposits, as evidenced by the presence of quartz bleached sands. The total flow rate of the spring is about 2 l/s. On the descent into the ravine, steps are made in the soil. Type of spring – descending.

Dachnyj spring is located on the territory of gardeners' non-commercial partnership "Sadovod" in the Gremyachaya ravine. The spring has several outputs: the first one was equipped with a concrete well and a canopy was built over the spring (currently there is no canopy). The waters of the spring, overflowing, form a wide stream with a width of about 2 m, this indicates a sufficiently high flow rate of the spring. But in the absence of captation, it is not possible to measure it. On the descent to the spring, steps are made in the soil. The second output is located at a distance of 20 m from the first one and is equipped with a metal pipe with a diameter of 2.5 cm. Its flow rate is 0.1 l/s. The third output is at a distance of not more than 1 m and it is not equipped. Flowing out its water connects with the second output spreading over the lowland, thereby forming wetlands overgrown with hydrophilic vegetation. Type of spring – descending.

Gremyachij spring is located at the base of the right slope of the Gremyachaya ravine at the entrance to Gorodishche village in Volgograd region, the height of which is about 50 m. The spring is equipped with a metal pipe with a diameter of 10 cm. Water-bearing horizon of the spring is formed at the base of Ergenian deposits. Type of spring – descending.

Serebryanyj kolodec spring is formed at the base of the right slope of the Gremyachaya ravine in Gorodishche village of Volgograd region. It has two outputs, one of which is in the form of a concrete well and is lidded. The second output is equipped in the form of a concrete well with a metal lid fixed with brackets to prevent external influences. At a distance of 25 meters, a metal pipe with a diameter of 4 cm comes to the surface to a small basin with steps. The flow rate of the spring is 0.2 l/s. The type of spring is ascending (table. 1) [2], [11], [12].

Of all the studied springs in Gorodishche village, water quality meets all standards only in one - Serebryanyj kolodec. The water in the spring has no smell and off-flavour (table. 1).

IV. CONCLUSION

A. Part one

Most of the groundwaters in the Central part of the Volga-Don interfluvium are located within the Volga-Khopersk artesian basin. The capacity of the freshwater

zone ranges from a few meters to 400 meters or more. The share of fresh water of the studied region accounts for 93 % of the explored water reserves, the forecast resources of which are 56 thousand m³/day. In the Central and Eastern part of the district there are brackish waters with a salinity of 1.0-3.0 g/dm³, the proportion of which is about 7%. This makes it possible to attribute the Central part of the Volga-Don interfluvium to areas with an average level of fresh groundwater availability.

B. Part two

There are more than 50 springs on the territory of the studied area, 19 of which were surveyed. The generalizing table on the studied springs is made, half of them belong to ascending, and another – to descending type. The flow rate of most of them is not high – from 70 to 200 ml. The current state of the springs in the Central part of the Volga-Don interfluvium meets most sanitary and epidemiological indicators and standards. It is also worth noting the good quality of water in Serebryanyj kolodec spring, located in Gorodishche village of Volgograd region.

TABLE I. MAIN ECOLOGICAL AND GEOLOGICAL-GEOMORPHOLOGICAL CONDITIONS OF SPRINGS IN GORODISHCHE VILLAGE

Name of springs	Main indicators						
	Water temperature in the spring, °C	Acid-base balance of spring water, pH	Flow rate, ml/sec	Number of outputs	Type of spring	Type of equipment and environmental condition	Geological-geomorphological conditions
Svyataya Paraskeva Pyatnica	+ 9	6.4	70	3	Ascending	Capped Equipped in the form of a well, the condition is satisfactory	On the left slope of the Korennaya ravine. Mechetin deposits.
Uvarovskij	+ 10	6	-	1	Ascending	Capped Equipped in the form of a well, the condition is not satisfactory	At the bottom of the Korennaya ravine. From Tsaritsyn deposits.
Gremyachi j	+ 9	6	112	1	Descending	Capped The spring is equipped in the form of a concrete pipe (diameter 10 cm), the condition is satisfactory.	At the foot of the right slope of the Gremuchka ravine. From Mechyotkinsk deposits.
Pridorozhnyj	+ 9	7	about 2000	3	Descending	2 outputs are equipped in the form of narrow long trays, the third output is not capped, the condition is satisfactory.	At the foot of the left slope of the right spur of Kamennyj Buerak. From Mechyotkinsk deposits.
Serebryanyj kolodec	+ 10	6.5	70	2	Ascending	1 output: made in the form of a square wooden frame, 2 output: it is equipped with a round concrete well, with a pipe coming into a square cupel.	At the foot of the left slope of the Gremuchka ravine. From Mechyotkinsky tier.
Dachnyj	+ 10	6.5	70	3	Descending	1 output: equipped in the form of a concrete well - water reservoir, 2 output: is not capped - water is dripping from the grotto, 3 output: it is equipped in the form of an iron pipe in the shape of the letter "Г" (4 cm in diameter).	At the foot of the right slope of the Gremuchka ravine. From Mechyotkinsk deposits.
Krasnyj pahar'	+ 10	7	-	1	Ascending	The spring is not equipped, spilling over the ravine, it forms dense thickets of moisture-loving vegetation.	At the foot of the dam of the first pond in the bed of the Rossoshka river, at the bottom of its slope. From Ergenian deposits.
Orlovskij	+ 10	6.5	About 200	1	Ascending	The spring is equipped. Four carved wooden pillars have a cruciform roof. Under it there is a low log house in the form of a well, which is closed with a metal lid.	At the right slope of the valley of the Orlovka river. From Mechyotkinsk deposits.
Shilkinskij (Erzovskij)	+ 10	7	About 200	1	Ascending	The spring is capped. it is equipped in the form of an iron pipe in the shape of the letter "Г" (4 cm in diameter).	At the base of the left slope of the right ravine opening into Yertzovsky Bay. In the lower horizon of Tsaritsyn deposits.
Svyatoj (Erzovskij)	+ 10	7	About 500	1	Ascending	The spring is equipped in the form of a drainage concrete well 200x120 cm in size, covered with a concrete lid. At a distance of about 2 m from the well, a metal pipe with a diameter of 10 cm comes into a metal drinking bowl with a length of 3 m.	At the base of the right slope of the right ravine opening into Yertzovsky Bay. In the lower horizon of Tsaritsyn deposits.
Zhuravl' (Erzovskij)	+ 10	7	About 500	1	Ascending	The spring is equipped.	At the base of the left slope of the right ravine opening into Yertzovsky Bay. In the lower horizon of Tsaritsyn deposits.

Dumenko-1	+ 12	7	Up to 2000	1	Descending	The spring is equipped in the form of a concrete drainage well with a diameter of 120 cm, covered with a metal lid. At a distance of about 4 m from the well there is a metal pipe with a circumference of 56 cm. There is a metal fence around the well	At the base of the left slope of the right ravine opening into Yerzovsky Bay. In the lower horizon of Tsaritsyn deposits.
Dumenko-2	+ 12	7	More than 1000	10	Descending	The source is not capped, has about 10 natural outputs on the day surface.	At the base of the left slope of the right ravine opening into Yerzovsky Bay, at a distance of about 20 m from the Dumenko-1 spring. In the lower horizon of Tsaritsyn deposits.
Volgolesos plav	+ 12	6.5	200	1	Descending	The spring is equipped in the form of a concrete water storage well with a depth of 2 m and a diameter of 120 cm, which is covered with a concrete slab. At a distance of about 3 m from the well there is a metal pipe with a diameter of 13 cm.	At the base of the left slope of the ravine opening into Yerzovsky Bay. In the lower horizon of Tsaritsyn deposits.
Serebryany j	+ 12	7	500	1	Descending	The spring is capped in the form of a metal pipe with a diameter of 13 cm, mounted in the base of the ravine.	at the base of the left slope of the Dubovaya ravine opening into Yerzovsky Bay. The spring belongs to the Tsaritsyn tier
Kuzmichevskij	+ 10	7	Up to 2000	2	Descending	The spring has two water outputs, located a few meters from each other, both are capped and equipped with pipes, one is metal with a diameter of 25 cm and the other is concrete with a diameter of 15 cm.	On the southern slope of the Konnaya ravine From Ergenian deposits.

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